Diet of the barracuda *Sphyraena guachancho* in Côte d'Ivoire (Equatorial Eastern Atlantic Ocean)

by

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Abstract. – The description of predator-prey interactions from trophic relationships are essential for understanding ecosystem functioning. We characterized and quantified the contribution of lower trophic levels in the diet of *Sphyraena guachancho* Cuvier, 1829, by season and size. Fish were sampled from commercial catches of the fishing port of Abidjan (Republic of Côte d'Ivoire, Equatorial Eastern Atlantic Ocean) between July 2010 and June 2011. A total of 318 specimens ranging from 19 to 63 cm fork length (FL) were examined. The vacuity index varied significantly between seasons with higher values in great cold season (71.3%), intermediate in the great and short dry seasons, 53.7% and 54.9%, respectively, and lowest in low cold season (48.9%). A total of 12 families were found in the stomachs of *S. guachancho*, mainly teleost fish species (mostly Clupeidae, Sphyraenidae, Carangidae and Engraulidae). Index of relative importance (IRI) was calculated for prey items found in guts to characterize diet and consisted of fish (IRI = 70.9%), cephalopods (IRI = 16.7%) and crustaceans (IRI = 12.4%). The IRI trend was the same during the warm and cold seasons, with the exception of January-February period where cephalopods were the dominant prey (IRI = 81.3%). A hierarchical cluster analysis highlighted diet similarities between individuals from size groups 19-24 cm FL, 24-54 cm FL and 54-63 cm FL. However, the first and the last size groups ate only fish while the intermediate size group consumed all three food groups (fish, cephalopods and crustaceans), including conspecifics (cannibalism).

Key words
Sphyraenidae
Sphyraena guachancho
Côte d'Ivoire
Diet

Résumé. – Régime alimentaire du barracuda *Sphyraena guachancho* en Côte d'Ivoire (océan Atlantique équatorial oriental).

La description des interactions prédateurs-proies à partir des relations trophiques sont essentielles pour la compréhension du fonctionnement d'un écosystème. Nous avons caractérisé et quantifié l'apport des niveaux trophiques inférieurs dans l'alimentation de *Sphyraena guachancho* Cuvier, 1829, par saison et par taille. Les échantillons sont issus des captures commerciales du port de pêche d'Abidjan (République de Côte d'Ivoire, océan Atlantique équatorial oriental) de juillet 2010 à juin 2011. 318 spécimens, dont la taille à la fourche était comprise entre 19 et 63 cm, ont été examinés. Le taux de vacuité des barracudas variait significativement entre les saisons avec les valeurs les plus hautes durant la grande saison froide (71,3%), intermédiaires aux grande et petite saisons sèches (respectivement 53,7% et 54,9%) et les plus faibles à la courte saison froide (48,9%). Au total, 12 familles ont été retrouvées dans l'estomac de *S. guachancho* (principalement Clupeidae, Sphyraenidae, Carangidae et Engraulidae). L'indice de relative importance (IRI) a été utilisé pour caractériser le régime alimentaire. Il est essentiellement constitué de poissons (IRI = 70,9%), puis de céphalopodes (IRI = 16,7%) et de crustacés (IRI = 12,4%). La tendance est la même pour toutes les saisons à l'exception des mois de janvier-février où les céphalopodes sont les proies les plus consommées (IRI = 81,3%). Une classification hiérarchique ascendante a mis en évidence des similarités alimentaires entre les individus appartenant aux groupes [19-24 cm FL], [24-54 cm FL] et [54-63 cm FL]. La première et la dernière classe, consomment exclusivement du poisson, alors que la classe de taille intermédiaire consomme les trois groupes de nourriture (poissons, céphalopodes et crustacés) y compris des con-spécifiques (cannibalisme).

The family Sphyraenidae is composed of voracious predators distributed in all equatorial, tropical and warm-temperate seas. They are economically important marine fish and their demand by local populations is great (Allam *et al.*, 2004; Kadison *et al.*, 2010). Large predators such as these pelagic fishes play a top-down role in ecosystem control (Baum and Worm, 2009; Lotze and Worm, 2009; Hunsicker *et al.*, 2012). Collapse of such apex predators due to environmental variability and/or effects of overfishing, impacts the lower trophic levels through the trophic cascade (Mc Peek, 1998; Chapin *et al.*, 2000; Cury *et al.*, 2003). In Côte d'Ivoire, the sphyraenid fishery is not yet regulated. Exploitation of sphyraenids, represented largely by the fishing of the barracuda *Sphyraena guachancho,* has increased from 3.5% in 1990 to 6.6% in 2007 (137 t to 292 t) of the national trawl catch (DPH, 2009). Since then, the catches are consid-

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erably lower (13.23 t) than in 1990 (DPH, 2011). The West African *Sphyraena guachancho* stock has also undergone a large decline as well as decrease in average individual size (Chavance *et al*., 2002; Gascuel *et al*., 2004). In the maritime space of Côte d'Ivoire, which lies in the Gulf of Guinea, a large diverse fishing flotilla harvests a wide number of different fish species. In this context, proper management of this top predator species necessitates an ecosystem-based approach, which relies heavily on knowledge of trophic relationships and food webs. In general, the literature on *Sphyraena guachancho* is not extensive. Cadenat (1964) briefly discussed the zoological characteristics of this species across West Africa, and a single study by Daget and Iltis (1965) in Côte d'Ivoire was limited to the identification and an overview of biological parameters of this species. The present study focuses on the characterization and quantification of lower trophic levels in the diet of *S. guachancho* in Côte d'Ivoire, in order to better understand their trophic role and interactions with other fish populations for an effective contribution to the management of their stock.

MATERIALS AND METHODS

Sampling

Barracudas were caught along the coast of Côte d'Ivoire (Fig. 1), which has 515 km of central Atlantic coastline. Its seasonal hydroclimatic conditions directly influence the availability of fishery resources due to a salinity of more than 35 and a surface sea temperature ranging from 23 to 30°C (Arfi *et al*., 1993). According to Morlière (1970), sea surface temperature is characterized by four distinct climatic periods. A great cold season (GCS), which extends from July to September. A cold episode or low cold season (LCS) is usually observed in December and February (temperature between 23°C and 25°C). The periods from March to June and October-November are called respectively large and short dry season (GDS and LDS) with temperature between 28 and 30°C.

Specimens of barracudas came from commercial catches from the fishing harbour of Abidjan. Trawlers, seiners, and purse seiners (that stored their catches immediately in ice after fishing) were visited monthly from July 2010 to June 2011. Based on the availability of barracudas, the sampling was oriented in order to obtain the widest range of possible sizes. The individuals were then measured (FL, cm), weighed (g), sexed, and maturity/gonad stage were recorded.

Fish gonads and stomach content analysis

The gonad maturity stages were recorded using the classification system of de Sylva (1963) with some modifications (immature, maturing, nearly ripe, ripe, spawning and spent stages) in accordance with Allam *et al*. (2004). Macroscopic food items were directly determined. Digested contents were observed under binocular microscope to identify microscopic or undigested items like otoliths. The different food items were identified to the lowest possible taxonomic level using an identification key by Daget and Iltis (1965) and FAO identification sheets for fishery needs (Fischer and Bianchi, 1981). All items were weighed (wet weight, g).

Study of food items and diet

Several indices were used to quantify the importance of different prey items in the diet of *Sphyraena guachancho*:

Vacuity index (VI) = (number of empty stomachs) / (total number of stomachs analysed) x 100 (Hureau, 1970).

Percentage frequency of occurrence:

$$(F) = Nie / Net \times 100,$$

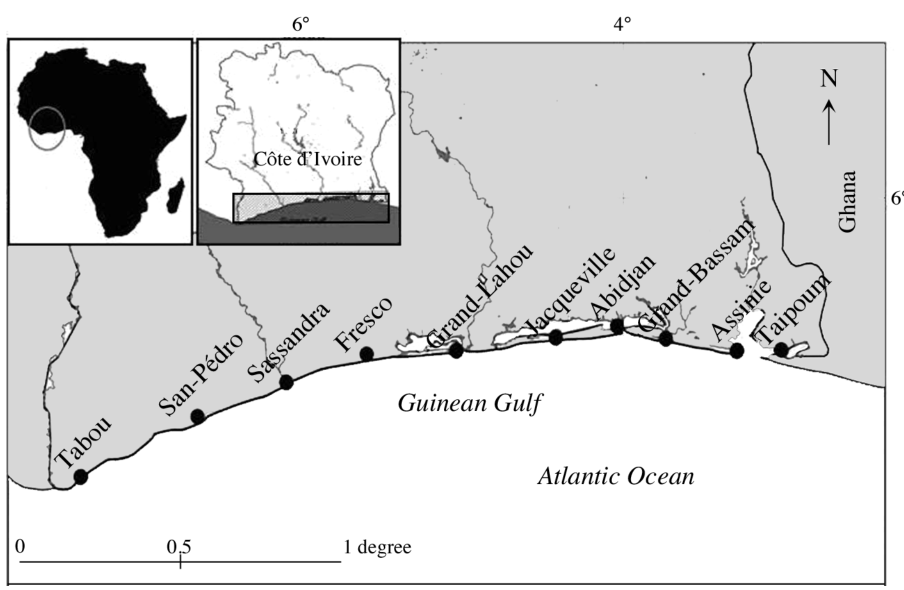

Figure 1. - Fishing zone (Côte d'Ivoire, West African) and coastal towns.

where Nie = number of stomachs containing item i and Net = total number of full stomachs examined (Rosecchi and Nouaze, 1987).

Numerical percentage of abundance:

$$(N) = Ni / Nt \times 100,$$

where Ni = total number of individuals of item i and Nt = total number of all food items (Hyslop, 1980).

Weight percentage:

$$(W) = Wi / Wt \times 100,$$

where Wi = total weight of item i and Wt = total weight of all food items inventoried (Lauzanne, 1977).

The diet was determined using the index of relative importance (IRI) of Pinkas *et al*. (1971). This index combines the occurrence (F), numerical (N) and weight (W) percentages:

$$IRI = F \times (N + W)$$

Prey species were sorted in decreasing order according to IRI and the cumulative IRI was calculated.

Determination of percentage stage and average length at maturity

Seasonal percentage of sexual maturity stage was calculated. Average length at maturity, i.e. when 50% of individuals (males and females combined) were mature, was applied to determine relationship between maturity state and diet profile of individuals (Gunderson *et al*., 1980). The percentage of sexual maturity was described by the logistic function:

$$P_x = 1 / 1 + e^{(ax + b)}$$

where P_x = percentage of mature fish at fork length x, and a and b = constants.

The values of L_{50} were estimated from the negative ratio (-b / a) with $\alpha = 0.5$.

Statistical analyses

All analyses were performed with the software Statistica 7.1. The χ^2 test was employed to compare the vacuity index by seasons ($\alpha < 0.05$). The IRI matrix by seasons was used to determine the significant differences in the diet between seasons with the Spearman rank coefficient (rs). According to Scherrer (1984), diets are exactly the same if rs = 1, independent if rs = 0, and strictly inverse if rs = –1. In order to group size classes of similar diet, a hierarchical cluster analysis (Ward method) was performed on the IRI percentages. Average length at maturity has been obtained by the logistic regression method.

RESULTS

Barracuda sizes ranged from 19 cm to 63 cm FL (n = 318; Fig. 2). They were grouped in 5 cm size classes with the exception of fish above 54 cm FL which were combined into one size class because of the small number of individuals (n = 3). Of the 318 analysed stomachs, 190 were empty.

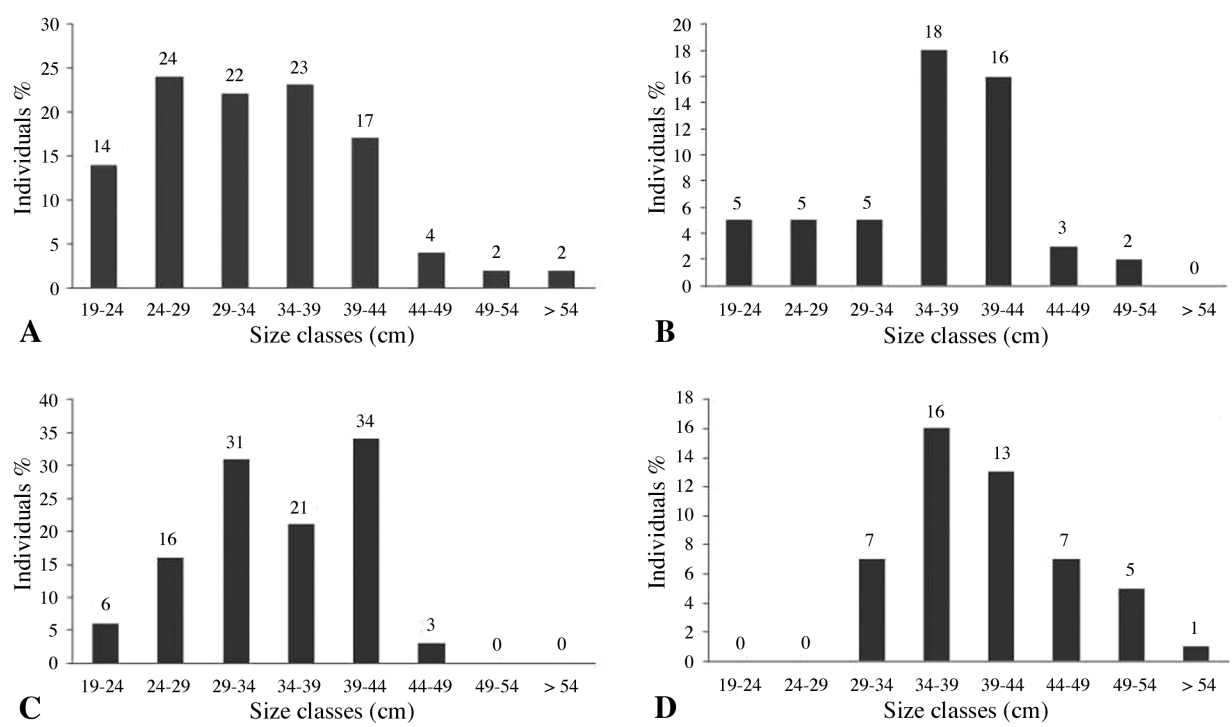

Figure 2. - Individuals percentage sampled by size classes in Great Cold Season (A), Great Dry Season (B), Low Dry Season (C), Low Cold Season (D). The number above each histogram correspond to the number of individuals.

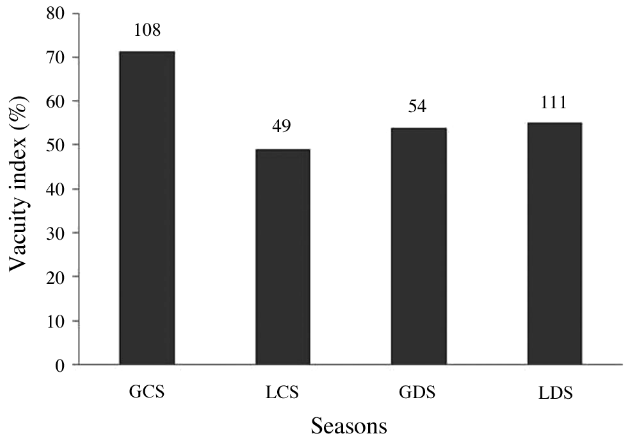

Figure 3. - Vacuity index by seasons; in Great Cold Season (GCS), Low Cold Season (LCS), Great Dry Season (GDS) and Low Dry Season (LDS). The number above each histogram correspond to the number of stomachs examined.

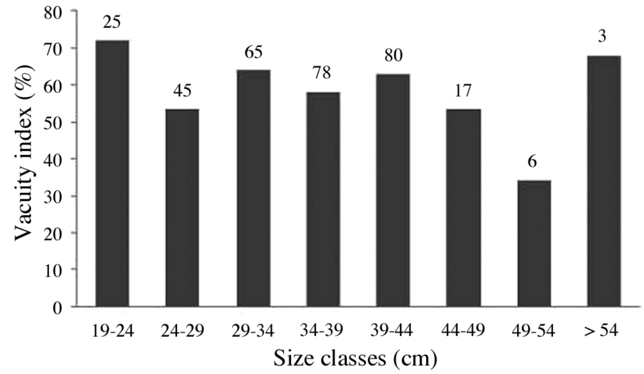

Figure 4. - Vacuity index percentage by size-classes of five centimetres. Length is fork length (cm). The number above each histogram correspond to the number of stomachs examined.

The mean vacuity index was 59.7% but varied with season (Fig. 3). It was significantly higher in GCS (71.3%) than in LCS (48.9%; $\chi^2 = 4.2896$; df = 1, p = 0.038). In the GDS and LDS, the vacuity percentages were similar (respectively 53.7% and 54.9%). All size classes had close vacuity index values ranging from 55 to 72.1%, with the exception of 49-54 cm size class which had the lowest index (33.3%; Fig. 4).

General profile of the diet

A total of 12 families of teleost fish and invertebrates were found in the stomachs of *Sphyraena guachancho* (Tab. I). Prey families were divided mainly into teleost fish (9), cephalopods (2) and Malacostraca (1). It was noted that these categories are ingested in different proportions throughout the size class and marine seasons. The main prey of *S. guachancho* were the clupeids *Sardinella* spp. (IRI = 22.5%) and *Ethmalosa fimbriata* (IRI = 18.8%) and the cephalopod *Teuthida* spp. (IRI = 14.0%). Secondary prey were the shrimp *Penaeus* spp. (IRI = 12.4%) and the carangid *Trachurus trecae* (IRI = 9.2%). *Sphyraena guachancho* were also a substantial prey item through cannibalism (IRI = 7.8%).

Table I. - List of prey found in the stomachs of *Sphyraena guachancho* caught along the coast of Ivory Coast from June 2010 to July 2011 with their occurrence percentage (F%), numerical percentage (N%), weight percentage (W%), and index of relative importance (IRI%).

Food items		F (%)	N (%)	W (%)	IRI (%)
Teleostei					
Carangidae	*Chloroscombrus chrysurus* (Linnaeus, 1766)	6.41	4.63	6.65	3.99
	Trachurus trecae Cadenat, 1950	7.69	5.56	16.01	9.17
Clupeidae	*Sardinella* spp.	16.67	12.04	12.39	22.50
	Ethmalosa fimbriata (Bowdich, 1825)	12.82	11.11	15.43	18.80
Engraulidae	*Engraulis encrasicolus* (Linnaeus, 1758)	7.69	10.19	2.91	5.57
Haemulidae	*Brachydeuterus auritus* (Valenciennes, 1832)	2.56	1.85	1.99	0.54
Polynemidae	*Galeoides decadactylus* (Bloch, 1795)	2.56	1.85	0.75	0.37
Sciaenidae	*Pseudotolithus* spp.	2.56	1.85	1.68	0.50
Sparidae	*Pagrus africanus* Akazaki, 1962	1.28	0.93	11.18	0.86
Sphyraenidae	*Sphyraena guachancho* Cuvier, 1829	10.26	7.41	6.31	7.77
Trichuridae	*Trichiurus lepturus* Linnaeus, 1758	1.28	0.93	11.19	0.86
Cephalopoda					
Sepidae	*Sepia* spp.	7.70	5.56	0.67	2.65
Teuthidae	*Teuthida* spp.	12.82	9.26	10.57	14.04
Crustacea					
Peneidae	*Penaeus* spp.	7.69	26.85	2.27	12.38
Total					
	Teleostei	71.79	58.33	86.49	70.93
	Cephalopoda	20.51	14.81	11.24	16.69
	Crustacea	7.69	26.85	2.27	12.38

Diet variation by season

Sardinella spp., *Teuthida* spp. and *Sphyraena guachancho* were consumed in all seasons but with large variation. For example, the relative importance of cephalopods in barracuda diet ranged from 0.5% IRI in GCS to 81.3% in LCS mainly dominated par *Teuthida* spp. (Fig. 5). *Sphyraena guachancho* diet was dominated by fish in GCS (IRI = 99.5%), GDS (IRI = 71.1%) and LDS (IRI = 66.8%; Fig. 5). The Spearman correlation test made between seasons shows that diets were independent of each other. Furthermore, in LCS and GCS, *S. guachancho* diet was inverse ($p < 0.05$, $r = -0.42$; Fig. 5).

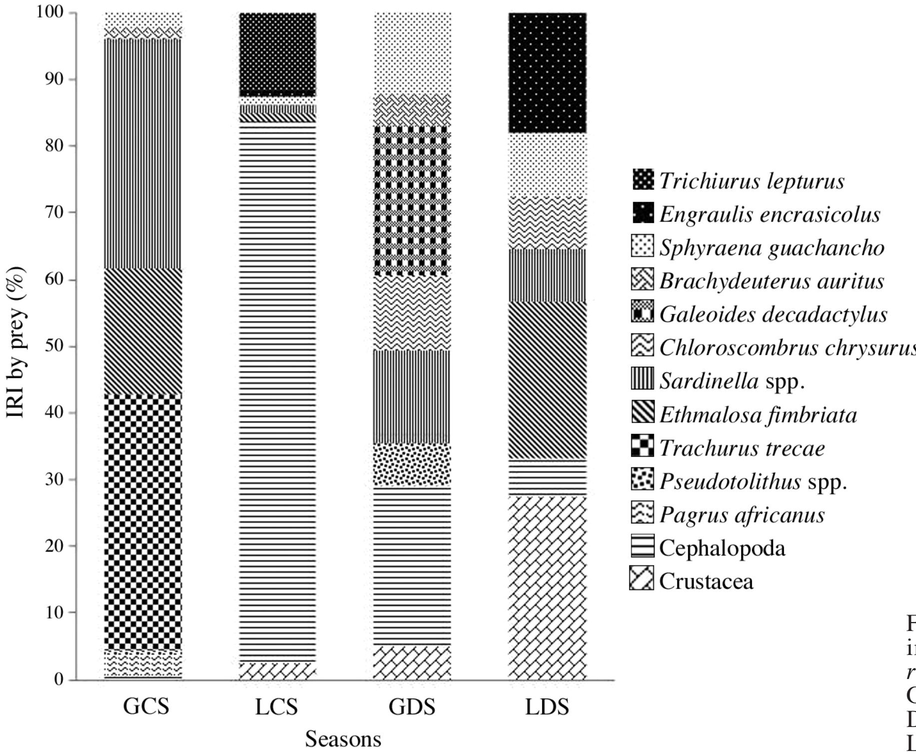

Figure 5. - Percentage of index of relative importance (IRI) for each prey of *Sphyraena guachancho* according to seasons. GCS = Great Cold Season, GDS = Great Dry Season, LCS = Low Cold Season, LDS = Low Dry Season.

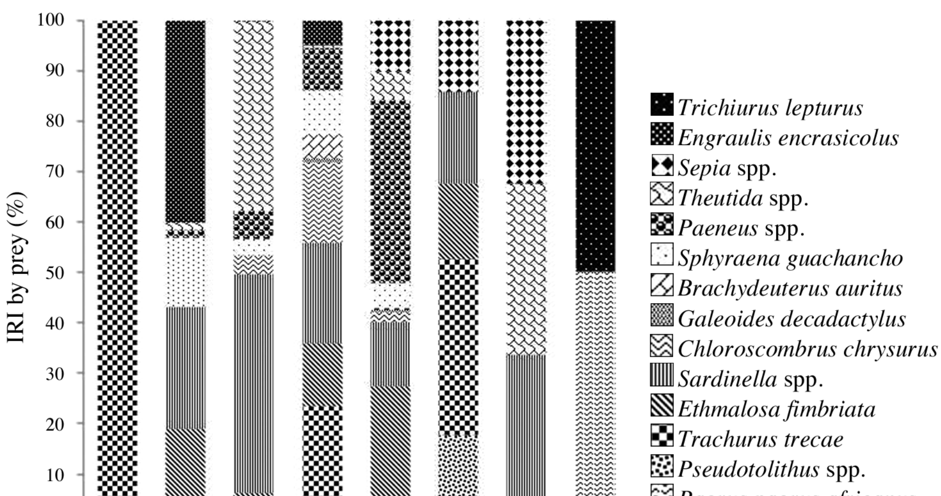

Figure 6. - Percentage of index of relative importance (IRI) for each prey of *Sphyraena guachancho* according to size classes.

Diet according to size classes and sexual maturity

In all size classes fish was the dominant food with the exception of size class 49-54 cm FL where cephalopods were the most consumed item (66.5% ; Fig. 6). Hierarchical cluster analysis showed similarities in diet between the different size classes. Three distinct groups were discriminated from the dendrogram (Fig. 7). Group 1 included individuals < 24 cm FL who eat only *Trachurus trecae*. Group 2 gathered individuals from 24 to 54 cm consuming mainly *Sardinella* spp., *Ethmalosa fimbriata*, *Sphyraena guachancho*, *Penaeus* spp. and cephalopods. Group 3 includes only the larger individuals (size > 54 cm FL) feeding on bigger size prey (*Trichiurus lepturus* and *Pagrus africanus*). The size at first maturity was 28.8 cm FL (Fig. 8). The larger and older mature stages (4 and 5) were observed in LCS and LDS up to 55% and 50% of individuals for stage 5 respectively, with

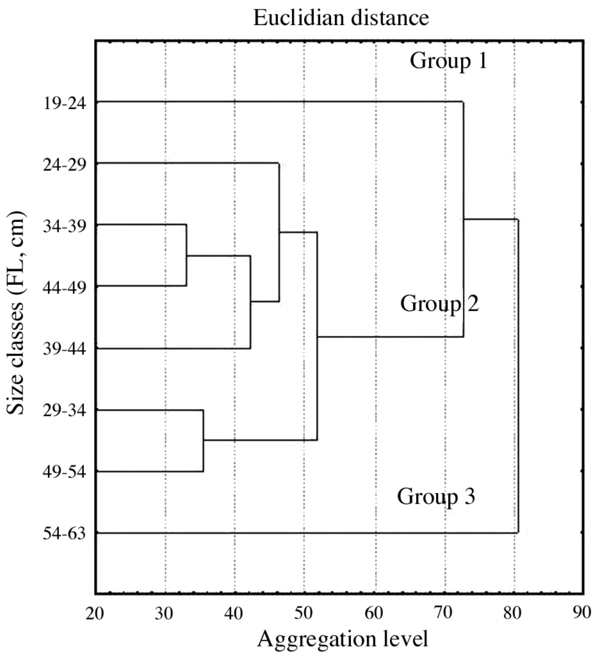

Figure 7. - Hierarchical cluster analysis (Ward method) obtained from the matrix of percentages of IRI by items in the eight size classes.

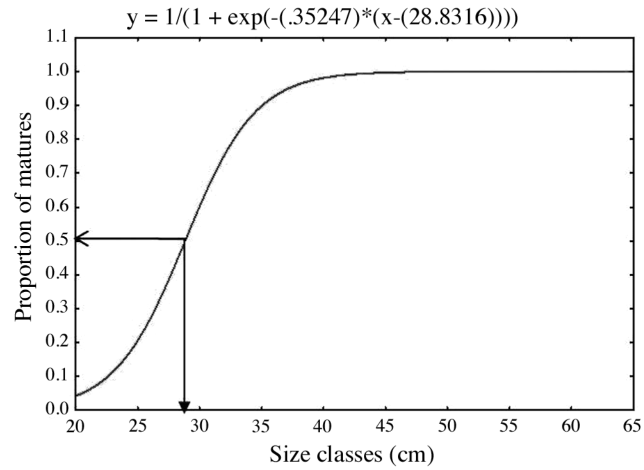

Figure 9. - Fork length at first sexual maturity (L50) for *Sphyraena guachancho* caught in Côte d'Ivoire littoral from June 2010 to July 2011.

lower maturity stages in GDS (Fig. 9).

DISCUSSION

Earlier writings describe *Sphyraena* species as voracious predators (Daget and Iltis, 1965). Indeed, its elongated lower jaw and protruding and strong teeth are made to pierce and expeditiously eat live prey (Pallaoro and Dulčić, 2001; Habegger *et al.*, 2010). The study of *Sphyraena guachancho* diet in Republic of Côte d'Ivoire coast (Eastern Central Atlantic) has shown that this pelagic species is principally piscivorous. This result is consistent with previous studies on other species of barracuda (De Sylva, 1963; Matsuura and Suzuki, 1997; Porter and Motta, 2004).

Our work based on stomach analyses has revealed that *S. guachancho* consumed three groups of prey, all of which were more pelagic than demersal. This result can be explained by the fact that *S. guachancho* itself is pelagic. These foods were fish, cephalopods and Malacostraca (twelve species, two species and one species listed respectively). This result is not in accordance with the work of Cervigon (1993) in the Western Atlantic, which does not mention crustaceans in the dietary regime of *S. guachancho*. In contrast, the FAO report (Fischer *et al.*, 1981) in our study area, confirms our observations. For other barracuda species, inhabiting other regions, similar diet was also found. Mala-

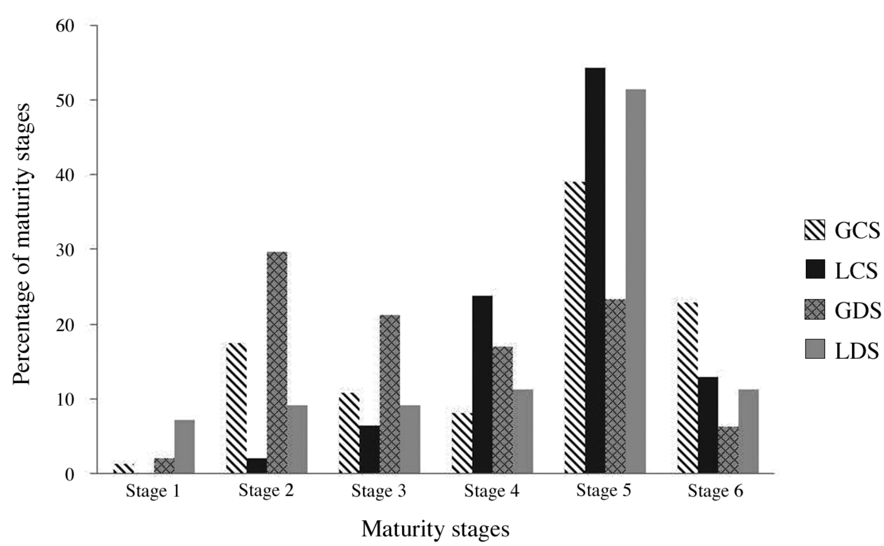

Figure 8. - Evolution of percentage of *Sphyraena guachancho* maturity stages by seasons. GCS = Great Cold Season, GDS = Great Dry Season, LCS = Low Cold Season, LDS = Low Dry Season.

costraca and cephalopods are regarded as supplements in the diet of *Sphyraena viridensis* and *Sphyraena chrysotaenia* in the Mediterranean Sea (Louisy, 2002; Kalogirou *et al.*, 2012). In general *Sphyraena guachancho,* which is largely piscivorous as most of the species of the genus are (Barreiros *et al.*, 2002), consumes more cephalopods than crustaceans. Changes in the mode to consumption of these three categories of prey vary depending on the species, the biomass available in the region, and the season (Grubich *et al.*, 2008).

Indeed during GCS, GDS and LDS, fish consumption was more important than other food groups. Clupeids were most abundant in their diet, specifically *Sardinella* spp. This result could be due to the high abundance of *Sardinella aurita* which represents up to 75-80% of total annual landings in Republic of Côte d'Ivoire (DPH, 2009). In these waters, the abundance of pelagic prey of *Sphyraena guachancho*, is influenced by the Coastal upwelling, mainly in GCS (Le Loeuff *et al.*, 1993). Thus, in GDS and LDS seasons, when there is no upwelling, these pelagic fishes could become scarce, and the barracuda diet becomes more diverse. It is likely that *S. guachancho* compensate for a lack of pelagic fish by opportunistically feeding on cephalopods and crustaceans during these warm periods.

In LCS, when the upwelling is less intensified, diet is dominated by cephalopods. This could be the result of very high abundance of cephalopods in the area during LCS. The decrease of the upwelling intensity alone is maybe not a sufficient explanation for this high abundance of cephalopods. We can hypothesised that the low abundance to their usual predators may help explain this variation (Faure *et al.*, 2008). In accordance, in GCS sparids appear in the stomachs of *S. guachancho* and cephalopods are absent. *S. guachancho* could also be in a food limited environment or in a sensitive physiological period (reproduction). For evidence, in LCS more than 50% of the fishes were mature. Therefore, this season could correspond to a reproductive period for *Sphyraena guachancho*.

If LCS is indeed a reproductive period, it does not correspond to a period of anorexia in this species (Akadje, pers. data). Effectively, there is a relatively high vacuity percentage through all the year with highest values in GCS. These high values of vacuity may be due to physiological disturbances related to potential capture mode or stress when they are captured, which can cause regurgitation of prey by fish by contraction of the esophagic muscle (Dierking and Meyer, 2009). However, according to Arrington *et al.* (2002) index of emptiness is positively correlated with trophic position of the fish.

The food composition ingested by individuals of different size classes was similar particularly among individuals between 24 and 44 cm. A dietary overlap was accordingly shown for nearly mature and mature fish. However, this dietary overlap decreased beyond these sizes. There was an ontogenic evolution in this diet. The larger the size of the barracuda is, the larger its prey is. In contrast, we found less diversity of prey in the diet of the larger individuals, which may be both due to the smaller number of barracuda sampled in the larger size classes and to the less diversity of large size prey. This result is consistent with that of Kalogirou *et al.* (2012) for Mediterranean barracudas species. A cannibalism effect was reported during the cold seasons and was more pronounced in hot weather. Cannibalism is common in some predators like the hake, cod and yellowfin (FAO, 1988; Guevara-Carrasco and Lleonart, 2008). For Alabi *et al.* (2009) the phenomenon is certainly a result either of ecological factors (possible lack of subsistence, high density of individuals, or structural heterogeneity of the population) or is a sociological factor (reproduction needs).

The predator *S. guachancho,* could also be subjected to a nutritional interspecific competition due to its trophic plasticity. Effectively, fish, cephalopods and crustaceans are also reported in the diet of large pelagic fish predators as for example, yellowfin tuna (*Thunnus albacares*), swordfish (*Xiphias gladius*) and lancetfish (*Alepisaurus ferox*) in Indian Equatorial Ocean (Potier *et al.*, 2007). In the Equatorial Atlantic Ocean competition might also occur, especially with tuna species that also feed on pelagic prey (Menard *et al.*, 2000). In Côte d'Ivoire, Scombridae, such *Scomberomorus tritor* or *Euthynnus alletteratus,* have also fish pelagic species as dominant part of their diet (Bahou *et al.*, 2007; Diaha *et al.*, 2010).

Global change, specially climatic warming will modify predator/prey relationships (Beaugrand *et al.*, 2002) in particular by the evolution of the species distribution areas (Albouy *et al.*, 2013). In the Equatorial Atlantic Ocean special caution must be brought to the consequence of the reduction of the intensity of upwelling, which may limit the nutritional needs of small pelagic fishes, causing decreasing in the prey availability of pelagic predators.

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